A COMPARISON OF FOREST FLOORS FROM PLANTATIONS OF THE SAME AGE AND ENVIRONMENT

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The forest floor, comprising the organic accumulation on the surface of the mineral soil, in addition to being a form of ecological reaction, has considerable importance in the development of the soil profile and in such matters as fertility, infiltration, surface runoff and erosion. Where forest vegetation is being used for the protection of eroding soil, the effectiveness of different species in contributing to the net accumulation of forest floor may be a consideration in the choice of species.

IN the years from 1932 to 1939, samples of forest floor have been collected from plantations of eight species, all 30 years old in 1939 and with the exception of the Canary pine, all growing on a north-facing exposure within 100 feet of the same altitude (about 800 feet above sea level), sloping 20 to 40 percent, and located east of the campus of the University of California at Berkeley. The soil has been classified as Altamont clay loam and appears to be essentially uniform in the different stands. The original vegetation was a mesic community dominated by species of Ceanothus, Rhus, Rhamnus, Ribes, and Rubus. The Canary pine habitat differs in that the exposure is south, the soil is more clayey, and the former vegetation was chiefly wild oats which had been grazed by cattle for many years. The trees were originally spaced 6 to 9 feet apart each way and now there remain from 230 to 810 to the acre. The canopies had closed before 1932 and the crown densities or coverage varied from 60 to 90 percent, sufficiently dense that there was little or no understory of vegetation. Thus a comparison of the forest floors is possible where the differences are attributable to the different tree species as they have developed in 23 to 30 years on the same site.

The rate of growth of the different species, however, has not been the same. The species may be arranged in the following descending order of tree size or volume and, since they are all of the same age, this is also the order of mean annual growth.

Redwood (*Sequoia sempervirens*)
Canary pine (*Pinus canariensis*)
Monterey pine (*Pinus radiata*)
Maritime pine (*Pinus pinaster*)
Douglas fir (*Pseudotsuga taxifolia*)
Madrone (*Arbutus menziesii*)
Monterey cypress (*Cupressus macrocarpa*)
Christmasberry (*Photinia arbutifolia*)

Presumably the volumes of crowns would follow the same order and also the accumulation of forest floor, if the latter process were not more or less balanced by decomposition.

The samples of forest floor were measured for depth and collected from areas of one square foot. All organic material above the mineral soil was included and observable bits of mineral matter rejected. An approximate separation was not difficult in these types. The 9 to 30 sampling points in each year were mechanically distributed in each stand at intervals of 6 or 8 feet, but not parallel to the rows of trees. The samples were weighed, sub-samples dried in an oven at 100° C., and the total oven-dry weights computed to metric tons per acre.

The figures for the median dry weights at 30 years, annual increases in dry weight, depths of floor, average diameters, heights and basal areas of the trees, and numbers of trees per acre are given for the different species in Table 1. The species are arranged in descending order of the dry weights of floor. For those stands in which collections were not made in 1939, the values from earlier years were adjusted by means of the figures for annual increase, so that they are comparable for the same age of 30 years. The mean dry weights exceed the median values by from 0.2 to 1.8 metric tons per acre but are considered to be less representative because they are more strongly influenced by a few exceptionally high values. Only one figure from the 414 samples was rejected because it was more than three times the standard deviation above the mean. The differences in means between species are statistically significant with the exception of those of Canary pine, Douglas fir, Monterey cypress, and redwood.

It is interesting that the three species of pine have the most forest floor, and that the two broad-sclerophyll species have the smallest amounts, with Douglas fir, Monterey cypress, and redwood occupying intermediate positions. Thus,

TABLE 1.—FOREST FLOOR AND STAND CHARACTERISTICS AT THIRTY YEARS

	Pinus radiata	Pinus pinaster	Pinus canariensis	Pseudotsuga taxifolia	Cupressus macrocarpa	Sequoia sempervirens	Arbutus menziesii	Photinia arbutifolia
Median dry weight of floor, metric tons per acre	24.3	14.2	12.6	12.5	12.4	11.2	9.7	4.8
Periodic annual increase in dry weight of floor, metric tons per acre	2.2	0.4	1.4	1.0		0.8	1.3	—
Mean annual increase, metric tons per acre	0.8	0.5	0.4	0.4	0.4	0.4	0.3	0.2
Average depth of floor in inches	2.8	2.3	3.0	1.5	1.0	1.6	1.9	0.9
Average diameter of trees at 4½ feet, inches	8.8	6.7	7.0	6.8	7.9	10.7	6.0	4.0
Average total height of trees, feet	50	31	39	43	38	51	30	12
Basal area per acre, square feet	121	175	180	99	78	212	115	73
Number of trees per acre	290	720	680	400	230	340	590	810
Number of years collected	4	2	2	4	1	5	4	1
Total number of samples	65	58	20	48	10	105	99	9

the order of species in amount of floor is not the same as that according to any of the stand characteristics. The redwood is decidedly larger than any of the others in diameter, basal area, and height, and several species have greater densities, in terms of number of trees per acre, than the Monterey pine which has the maximum forest floor. Conversely, maritime pine and Monterey cypress which rank fourth and seventh in average size are second and fifth, respectively, in amount of floor. On the whole, the amount of forest floor cannot be considered to be a function of the growth or of any other characteristics of the stands.

The lack of agreement presumably is attributable to differences in rate of decomposition. These in turn might be related to the geographic distribution and consequent degree of adaptation to the site. The madrone and Christmasberry with the smallest amounts of floor are native on the same slope. The redwood and Douglas fir, having relatively low amounts of forest floor, are the two species which grow naturally only short distances from the location of the plantations, namely within about 6 and 15 miles, respectively. The Monterey pine and Monterey cypress are found 100 miles to the south. The maritime and Canary pines have been introduced from the Mediterranean region. The three pines have the largest accumulations of floor. Examinations of the forest floor in natural stands of mature redwood, Douglas fir, and Monterey pine suggest that the amounts are not widely different from those found in these plantations. Christmasberry in the San Gabriel mountains 14 years after the last fire, averaged 7.2 metric tons per acre,[1] as compared with 4.8 in this plantation. The effectiveness of the different species in the development of forest floor apparently may be somewhat related to the distance from their native habitat or to the degree of adjustment of local micro-organisms in promoting decomposition. In other words, there is some indication that the farther a species is from its native habitat, the more floor accumulates.

The annual increases in dry weight of floor were obtained in the case of periodic increase by dividing the difference between the median collections in different years by the number of years in the period, and in the case of the mean, by dividing the total by the age. Insofar as the amount of forest floor is a function of the annual accumulation, the increase should be related to the rate of growth of the trees. At 30 years, the growth and foliage production should be approaching maxima, and the latter is certainly higher than was the case before closure of the crowns. Hence, the annual accumulation of litter should be increasing and by analogy with the growth of stems, the periodic annual increase should be in excess of the mean annual. This is the case, with one exception. On the other hand, the fact that older natural forests of the same species do not have excessive amounts of floor or indeed more than in these plantations, indicates

[1] Kittredge, J., Jr. The forest floor of the chaparral in San Gabriel mountains, California. Jour. Agric. Research 58: 521-535. 1939.

that a point is reached at which accumulation is balanced by decomposition. It is somewhat surprising to find that this stage has not been reached in 30 years. This may be because of the density of these plantations for presumably the maximum would come at later ages in denser stands where solar radiation and temperature are less favorable to decomposition, than in more irregular and more open natural stands. The balance between accumulation and decomposition may be indicated for the Canary pine by comparing the average annual accumulation of 2.7 metric tons per acre, derived from collections in a 3 by 3-foot tray for each of the years, 1936 through 1939, with the net periodic annual increase of 1.4 tons, leaving 1.3 tons annually for decomposition. The figures for mean annual increase, of course, follow the same order as for total dry weight. Those for periodic annual increase are not wholly consistent, maritime pine specifically showing an increase of 0.4 metric ton per acre, a much lower figure than would be expected, which may be a reflection in part of differences in sampling in different years. The figure of 2.2 metric tons per acre for Monterey pine is notably high, considering that it represents the net result of accumulation and decomposition. Apparently, this species is outstanding in the production of forest floor.

The depths of forest floor vary from 3 inches for Canary pine and 2.8 inches for the Monterey pine to 0.9 inch for the Christmasberry, again corresponding roughly to the order of total dry weight. The lack of strict correspondence is obviously associated with differences in apparent density of the floor. Determinations of volume weight for three of the species, gave averages of 0.05 for madrone and 0.06 for redwood and maritime pine. The depths of floor in these plantations may be greater than in dense natural old-growth forests as indicated by comparison of the 1.6 inches for redwood and 1.5 inches for Douglas fir with the 0.6 and 1.1 inches for the same species reported by Bodman and Kittredge[2] from northern California. All these plantations had produced forest floor in amounts ample for the protection of the soil from erosion before they were 23 years old.

Summary

By way of summary, the following points may be emphasized.

1. Plantations 30 years old in the same environment produced forest floor in decreasing amounts from Monterey pine with 24.3 metric tons per acre, through maritime pine, Canary pine, Douglas fir, Monterey cypress, redwood and madrone, to Christmasberry with 4.8 metric tons per acre.

2. The differences between species are statistically significant except for the Canary pine, Douglas fir, Monterey cypress, and redwood which have median values between 11.2 and 12.6 metric tons per acre.

3. The amounts of forest floor are not consistently related to the size, density, or growth of the stands.

4. The species growing naturally on or near the area tend to have less forest floor than those introduced from distant localities.

5. The net amounts of floor up to 30 years are continuing to increase at rates in excess of the mean annual.

[2]Bodman, G. B. and J. Kittredge, Jr. Descriptions of forest floors from several important forest types of the Sierra Nevada, basalt plateau and coast ranges in northern California. Proc. Soil Sci. Soc. Amer. 2: 509-21. 1938.